CLAIMS:

1. Apparatus for direct digital generation of a synthesized RF signal with phase modulation comprising:

a high speed reference clock providing in an input signal having a series of signal reference edges at a frequency of the reference clock which is higher than the desired output frequency;

programmable digital delay elements arranged to receive the reference edges of the input reference clock and to generate delayed signal edges each at a calculated delay from a respective reference edge;

wherein the programmable digital delay elements include an input element for receiving data defining a required phase modulation and providing a delay value for said calculated delay;

and a signal combining element for receiving the delayed signal edges and for generating the RF signal therefrom.

2. The apparatus according to Claim 1 wherein the programmable digital delay elements comprise high speed adders/accumulators wherein said adders/accumulators are arranged to determine the amount of delay implemented by the delay elements on the reference edge.

3. The apparatus according to Claim 1 wherein the programmable digital delay elements comprise high speed adders/accumulators and a look-up table for providing increments to be added to calculate said delay.

4. The apparatus according to Claim 3 wherein the lookup table has a multiple set of lookup tables to be used for temperature compensation of the

programmable delay line.

5. The apparatus according to Claim 1 wherein the reference clock provides an external input with high frequency absolute accuracy and very low phase noise performance.

6. The apparatus according to Claim 1 wherein the programmable digital delay elements are arranged such that said reference edge may be either the rising or falling edge of the reference clock.

7. The apparatus according to Claim 1 wherein said programmable digital delay elements have separate controls for producing the rising and falling edges of the output from the same input edge of the reference clock.

8. The apparatus according to Claim 1 wherein the programmable digital delay elements are arranged to be varied by altering the input clock signal.

9. The apparatus according to Claim 2 wherein in association with the high speed adders/accumulators of the programmable delay elements there is provided a pulse swallow circuit which is controlled by the carry bits (overflow bits) of the high speed adders/accumulators in order to extend the delay to multi cycles of the input reference clock.

10. The apparatus according to Claim 9 wherein the pulse swallow circuit is arranged to discard multiple reference clock pulses.

11. The apparatus according to Claim 9 wherein said pulse swallow circuit is located prior to or following the programmable delay element.

12. The apparatus according to Claim 1 wherein the programmable digital delay elements are arranged such that 360 degrees of phase delay of the

programmable delay is calibrated to 2^n of the phase accumulator value using a look up table or microprocessor.

13. The apparatus according to Claim 1 wherein the programmable digital delay elements comprise high speed adders/accumulators wherein said adders/accumulators are arranged to determine the amount of delay implemented by the delay elements on the reference edge and wherein the input element comprises a modulation adder for providing a value to be added to the delay from said accumulator/adders.

14. The apparatus according to Claim 13 wherein said modulation adders are arranged to add in the positive or negative phase offset to the accumulator value to produce the required modulation.

15. The apparatus according to Claim 13 wherein there is provided an interpolator which is arranged to interpolate the sampled base band modulated information to provide said data for said modulation adder.

16. The apparatus according to Claim 15 wherein the interpolator is a linear interpolator or a sin x/x interpolator filter.

17. The apparatus according to Claim 15 wherein the interpolator is arranged such that the need for a reconstruction filter is removed by interpolation up to the reference clock rate.

18. The apparatus according to Claim 15 wherein there is provided a plurality of separate interpolators for both the rising and falling pulse edges.

19. The apparatus according to Claim 1 wherein the signal combining element comprises a flipflop.

20. The apparatus according to Claim 19 wherein said flipflop is arranged to combine the separate rising and falling edge delays to form any desired duty cycle output.

21. The apparatus according to Claim 20 wherein said output duty cycle is not dependent on an input duty cycle of the input signal.

22. The apparatus according to Claim 20 wherein said duty cycle of the output can be varied by changing the difference in initialization values of the programmable digital delay elements for the rising and falling edge delay control.

23. The apparatus according to Claim 2 wherein the output frequency is set from an increment value according to the following equation:

$$\text{Increment Value} = ((f_{ref} / f_{out}) - 1) * 2^n$$

where $f_{ref}$ = Reference clock (103) frequency

$f_{out}$ = Output (110) frequency

n = Number of bits in the accumulator math.

24. The apparatus according to Claim 2 wherein the duty cycle is set by initializing the difference of the initializing values of the two accumulators according to the following equation:

The reference clock frequency divided by the desired output frequency multiplied by $2^{\wedge n}$ multiplied by (p/100), where p is the percentage duty cycle and n is the number of bits in the accumulator math.

25. The apparatus according to Claim 2 wherein the worst case frequency resolution is determined by the equation: The reference frequency divided by $2^{\wedge n}$, where n is equal to the number of bits in the accumulator.

26. The apparatus according to Claim 2 wherein the number of bits of math used in the adder can be equal to or exceed the number of bits of control in lookup table and /or the programmable delay.

27. The apparatus according to Claim 1 wherein the speed can be increased using parallel processing in the adders, and/or accumulators.

28. The apparatus according to Claim 2 wherein the adders/accumulators is implemented in a larger lookup table wherein all the answers of the pattern are precomputed and stored.

29. The apparatus according to Claim 1 wherein the components are formed fully digitally in an ASIC with no requirement for a voltage controlled oscillator, loop filter, or Digital to Analog converter.

30. The apparatus according to Claim 1 wherein there is further provided amplification and filtering of the output to produce a signal that is higher in amplitude and/or having less harmonics.